

FORM PTO-1390
REV. 2/01T

U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

ATTORNEY'S DOCKET NUMBER
05788 0198
Customer No.: 22,852U.S. APPLICATION NO.
(If known, see 37CFR1.5)**10/019479**

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/06205	July 3, 2000	July 1, 1999

**TITLE OF INVENTION: OPTICAL WAVEGUIDES DERIVED FROM A COMBINATION OF
POLY(PERFLUOROCYCLOBUTANES) AND POLYMERIC CYANATES**

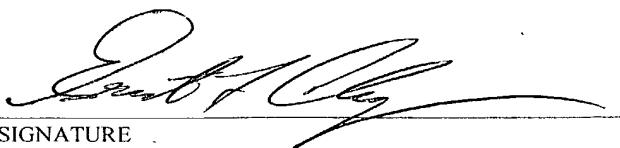
APPLICANTS FOR DO/EO/US: 1) Monika BAUER, 2) Jörg BAUER, 3) Christian DREYER, 4) Norbert KEIL, and
5) Crispin ZAWADZKI

Applicants herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. This is a **FIRST** submission of items concerning a filing under 35 U.S.C 371.
2. This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. A copy of the International Application as filed (35 U.S.C. 371 (c)(2)).
 - a. is attached hereto (required only if not communicated by the International Bureau).
 - b. has been communicated by the International Bureau.
 - c. is not required, as the application was filed with the United States Receiving Office (RO/US).
6. An English language translation of the International Application as filed (35 U.S.C. 371 (c)(2)).
 - a. is attached hereto.
 - b. has been previously submitted under 35 U.S.C. 154 (d)(4)
7. Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3)).
 - a. are attached hereto (required only if not communicated by the International Bureau).
 - b. have been communicated by the International Bureau.
 - c. have not been made; however, the time limit for making such amendments has NOT expired.
 - d. have not been made and will not be made.
8. An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. Information Disclosure Statement under 37 CFR 1.97 and 1.98
12. An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. A **FIRST** preliminary amendment.
14. A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. A Substitute specification.
16. A change of power of attorney and/or address letter.
17. A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1821-1.825.
18. A second copy of the published international application under 35 U.S.C. 154 (d)(4).
19. A second copy of the English language translation of the international application 35 U.S.C. 154 (d)(4).
20. Other items or information:
 - a. Copy of cover page of International Publication No. **WO 01/02880**.
 - b. Copy of Notification of Missing Requirements.

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/019479	INTERNATIONAL APPLICATION NO. PCT/EP00/06205	ATTORNEY'S DOCKET NUMBER 05788 0198
21. <input checked="" type="checkbox"/> The following fees are submitted:		CALCULATIONS PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO		\$1040.00
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO		\$890.00
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search fee (37 CFR 1.445(a)(2)) paid to USPTO		\$740.00
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)		\$710.00
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33 (1)-(4)		\$100.00
ENTER APPROPRIATE BASIC FEE AMOUNT =		
Surcharge of \$130.00 for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)).		<input type="checkbox"/> 20 <input type="checkbox"/> 30 \$
CLAIMS	NUMBER FILED	NUMBER EXTRA
Total Claims	12	- 20 = 0
Independent Claims	1	-3 = 0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		+\$280.00 \$280.00
TOTAL OF THE ABOVE CALCULATIONS =		
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.		\$
SUBTOTAL =		
Processing fee of \$130.00 for furnishing the English translation later than months from the earliest priority date (37 CFR 1.492(f)).		<input type="checkbox"/> 20 <input type="checkbox"/> 30 \$
TOTAL NATIONAL FEE =		
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property.		+\$ \$
TOTAL FEES ENCLOSED =		
		Amount to be refunded.
		charged: \$
a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>1170.00</u> to cover the above fees is enclosed.		
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.		
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>06-0916</u> . A duplicate copy of this sheet is enclosed.		
d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.		
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.		
SEND ALL CORRESPONDENCE TO:		
Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P. 1300 I Street, N.W. Washington, D.C. 20005-3315 EFC/FPD/sci DATED: December 31, 2001		
 SIGNATURE Ernest F. Chapman/25,961 NAME/REGISTRATION NO.		

10/01/9479
JC13 Rec'd PCT/PTO 31 DEC 2001

PATENT
Customer No. 22,852
Attorney Docket No. 05788.0198

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:)
Monika BAUER et al.) Group Art Unit: Not Yet Assigned
Serial No.: Unassigned) Examiner: Not Yet Assigned
PCT Filed: July 3, 2000)
U.S. National Stage Filed: December 31, 2001)
)

For: **OPTICAL WAVEGUIDES DERIVED
FROM A COMBINATION OF
POLY(PERFLUOROCYCLOBUTANES)
AND POLYMERIC CYANATES**

National Phase Filing of International
Application No. PCT/EP00/06205

Box PCT
Assistant Commissioner for Patents
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

Prior to the examination of the above application, please amend this application as follows:

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 1, after the title, please insert the following new headings and subheadings and new paragraph:

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Attorney Docket No. 05788.0198

--Cross Reference to Related Applications

This application is a national stage filing of International Application No. PCT/EP00/06205, filed July 3, 2000, which published in the English language and claims priority of European Patent Application No. 99112597.2, filed on July 1, 1999.

BACKGROUND OF THE INVENTION

Field of the Invention--.

Page 1, before line 34, add the following new subheading:

--Description of the Related Art--.

Page 3, before line 19, add the following new section heading:

--SUMMARY OF THE INVENTION--.

Page 3, before line 30, add the following new section heading:

--DETAILED DESCRIPTION OF THE INVENTION--.

IN THE CLAIMS:

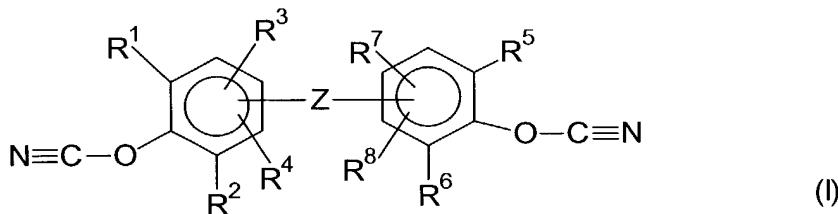
Please cancel now pending claims 1-5 without prejudice or disclaimer and substitute new claims 6-11 therefor as follows:

WHAT IS CLAIMED IS:

6. (New) An optical waveguide system or waveguide structure comprising at least (a) a first material which is a poly(perfluorocyclobutane), and in direct contact with this material (b) a second material which is a polycyanate resin, wherein the polycyanate resin has been (co)polymerized from at least one difunctional cyanate of formula I:

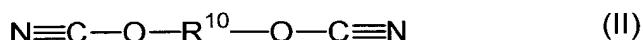
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wherein R¹ to R⁸ are independently from each other hydrogen, optionally substituted C₁-C₁₀ alkyl, C₃-C₈ cycloalkyl, C₁-C₁₀ alkoxy, halogen, phenyl or phenoxy, the alkyl or aryl groups being unfluorinated, partly fluorinated or fully fluorinated, with the proviso that (I) carries at least 1 fluorine atom, and Z is a chemical bond, SO₂, CF₂CH₂, CHF, CH(CH₃), isopropylene, hexafluoroisopropylene, n- or iso-C₁-C₁₀ alkylene which may be partly or fully fluorinated, O, NR⁹ whereby R⁹ is hydrogen or C₁-C₁₀ alkyl, N=N, CH=CH, C(O)O, CH=N, CH=N-N=CH, alkyloxyalkylene having 1 to 8 carbon atoms, S, or Si(CH₃)₂.

7. (New) An optical waveguide system or waveguide structure as claimed in claim 6, wherein the polycyanate resin has been copolymerized from at least one dicyanate of formula I and at least one difunctional cyanate of formula II:



wherein R¹⁰ is C(R')₂-R"-C(R')₂, wherein each R' is, independently from the other, hydrogen or fluorine or an optionally substituted alkyl or alkenyl group, and R" is a non-aromatic hydrocarbon group or may have an arylenic structure, with the proviso that (II) carries at least one fluorine atom.

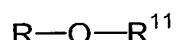
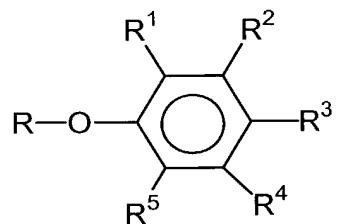
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8. (New) An optical waveguide system or waveguide structure as claimed in claim 7, wherein the optionally substituted alkyl or alkenyl group of R' is fluorinated.

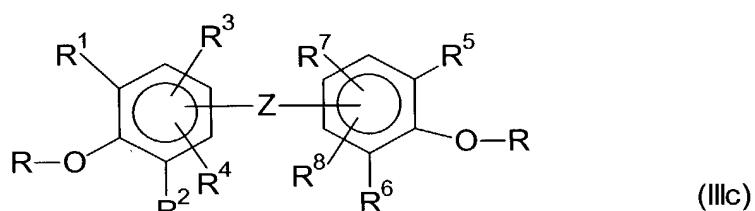
9. (New) An optical waveguide system or waveguide structure as claimed in claim 7, wherein the polycyanate resin has been copolymerized from at least one dicyanate of formula I, optionally at least one difunctional cyanate of formula II, and at least one of the following compounds:

monocyanates having formula IIIa or IIIb:



wherein R¹ to R⁵ are as previously defined for the dicyanate of formula I, R is N≡C- and R¹¹ is a straight, branched, or cyclic non-aromatic hydrocarbon radical or a non-aromatic hydrocarbon radical comprising a cyclic structure,

phenols having either formula IIIa above or formula IIIc:



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wherein Z and R¹ to R⁸ are as defined above for formula I and R is hydrogen,

monoalcohols having formula IIIb wherein R¹¹ is as defined above, and wherein R is hydrogen,

non-aromatic dihydroxy compounds having formula Vd



wherein R is hydrogen and R¹⁰ is as defined for the dicyanates of formula IV above,

and

glycidethers of formulas IIIa to IIIc wherein R is glycidyl, the other radicals being as defined above.

10. (New) An optical waveguide system or waveguide structure as claimed in any of one of claims 6 to 9, wherein both the first and the second materials are in the form of a thin layer, the layers directly adhered to each other.

11. (New) An optical waveguide system or waveguide structure according to claim 10, wherein either the waveguide is made of the first material and at least one of a buffer layer and a cladding layer is made of the second material, or the waveguide is made of the second material and at least one of a buffer layer and a cladding layer is made of the first material.

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Attorney Docket No. 05788.0198

REMARKS

In this Preliminary Amendment, the claims have been amended to conform them to U.S. practice.

Claims 6-11 are pending in this application. No new matter has been added.

If there is any fee due in connection with the filing of this Preliminary Amendment, please charge the fee to our Deposit Account No. 06-0916.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW,
GARRETT & DUNNER, L.L.P.

Dated: December 31, 2001

By:


Ernest F. Chapman
Reg. No. 25,961

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WO 01/02880

PCT/EP00/06205

1

Optical waveguides derived from a combination of poly(perfluorocyclobutanes) and polymeric cyanates

The present invention is directed to waveguides or waveguide structures prepared from organic (co-)polymeric cyanates and poly(perfluorocyclobutanes).

Organic polymers are increasingly interesting materials in the optical or microoptical field, in integrated optics or in microsystem techniques. In these fields, they may be used in optical instruments and apparatuses or parts thereof as well as in special optics as lenses, prisms, for fixation of optical systems, as support materials for optical layers and as translucent coating materials for mirrors or lenses. Organic polymers may be used in optical fibres and for the preparation of waveguide structures. Their technical handling is relatively easy, and their density is lower in comparison to glass.

Specifically, if such plastics or organic polymers are to be used as a waveguide, a variety of requirements are to be met. The refractive index of the material should be variable in a range as broad as possible and should be adaptable to that of specific substrates. If used in the optical communication engineering, low absorptions of the materials are required at 1.3 and 1.55 μ m. The loss due to attenuation caused by volume defects (non-homogenities, microbubbles, microfissures) should be minimized. Besides specific technological requirements, e.g. preparation of layers and structurability, specific provisions for the use of organic polymers as waveguide structures in integrated optics are the thermal and thermo-mechanical stability, adapted extension coefficients and long term stability of optical properties.

Until now, polymethacrylates and polycarbonates have been mainly used for optical purposes. Both classes of polymers have an excellent light transmittance, but their thermal and thermo-mechanical stability is not sufficient due to their chemical structure. Thus, polymethacrylates and polycarbonates cannot

practically be used at temperatures exceeding 130°C which is due to their relatively low glass transition temperatures. In addition, both types of polymers are linear, un-crosslinked polymers. This has the adverse effect that they are partly solubilized in case multilayer-systems are prepared via the application of dissolved components, e.g. by spin-coating each layer. Consequently, the layer structures as obtained are not sufficiently delimitated and neat which, however, is an essential for the preparation of waveguide structures.

10

There are other high performance polymers which have glass transition temperatures of more than 180°C. Examples are polyarylethersulfones, polyarylsulfones, polyaryletherketones, polyimides and polyetherimides, the processing of which, however, is more difficult than that of polymethacrylates and polycarbonates. Another disadvantage of these systems is the relatively high optical loss at wave lengths of 1.3 and 1.55μm, relevant in communication engineering.

20

Polyperfluorocyclobutanes (PFCB) are a relatively new class of high performance polymers. They have first been described by Babb and others. in US patents 5.037.917, 5.037.918, 5.037.919, and 5.159.038. Upon thermal curing they yield insoluble cross-linked polymers which are characterized by high thermal stability. Waveguides prepared from PFCB in combination with buffer layers made of thermally grown SiO₂ have been described by Fischbeck et al., Electronic letters 33, 518 (1997). The layers prepared from PFCB showed very low optical losses at 1550 nm (minimum: 0.2 dB/cm). Polymeric waveguide systems consisting of more than one organic polymer are not described in this paper.

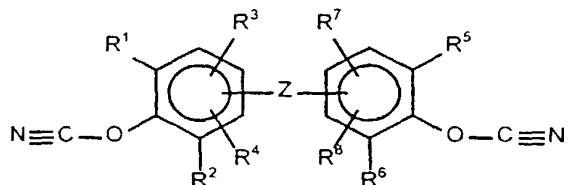
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In addition, it is known to use polycyanurates for the preparation of optical components. US patents 5 208 892 and 5 165 959 describe the preparation of polycyanate resins made of a single monomer (either fluorinated or non-fluorinated). German Offenlegungsschrift DE 44 35 992 A1 describes optical elements prepared from polycyanurate resins. The resins are made by polymerization of dicyanate or polycyanate compounds, optionally

The polycyanate resins (polymeric cyanates) may be selected from those which have a rather low refractive index adapted to that of the PFCB chosen. According to the invention, the said polymeric cyanates are formed by polymerization or 5 copolymerization of at least one specific organic aromatic difunctional cyanate as defined below, preferably in combination with one or more of other mono- or difunctional cyanates, the polymeric cyanates consisting of or containing at least one difunctional monomer which is partly or fully fluorinated, and 10 optionally in admixture with other substances as defined below.

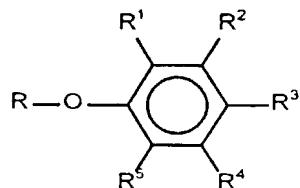
"Partly fluorinated" means that at least one fluorine atom is present in the molecule. "Fully fluorinated" means that hydrogen atoms are completely substituted by fluorine atoms. The whole 15 molecules, or single organic radicals or groups (e.g. methyl, methylene, alkyl, aryl groups), respectively, may be fully fluorinated. For the preparation of the said polymeric cyanates, one, two, three or even more monomeric cyanates may be used. The NCO groups of the cyanate monomers are bound to organic radicals 20 via the oxygen atom.

The aromatic difunctional cyanate to be used in the present invention has a structure as given in formula I below (with the proviso that the or at least one of the cyanates chosen for 25 (co-)polymerization carries at least one fluorine atom):



(I)

wherein R¹ to R⁴ and R⁵ to R⁸ are independently from each other hydrogen, optionally substituted C₁-C₁₀ alkyl, C₃-C₈ cycloalkyl, 30 C₁-C₁₀ alkoxy, halogen, phenyl or phenoxy. The alkyl or aryl groups may be unfluorinated or they may carry at least one fluorine atom. In one embodiment, at least one of the alkyl or aryl groups present in the molecule is fully fluorinated. In another embodiment, the difunctional cyanate molecule is fully



IIIa

5 R-O-R¹¹

IIIb

wherein R¹ to R⁵ are as previously defined for the dicyanates of formula I, R is N≡C- and R¹¹ is a straight, branched, or cyclic non-aromatic hydrocarbon radical or a non-aromatic hydrocarbon radical comprising a cyclic structure. Preferably, the alkyl radical has 1 to 15, more preferably 3 to 12 carbon atoms.

Preferably, at least one fluorine atom is present in the monocyanate of formula IIIa or IIIb. If fluorine atoms are present in formula IIIb, R¹¹ is C(R')₂-CFR"₂, wherein each R' is, independently from the other, hydrogen or fluorine or an optionally substituted, preferably fluorinated alkyl or alkenyl group having preferably 1 to 13, more preferably 3 to 11 carbon atoms. Each of R" may independently be defined as R'.

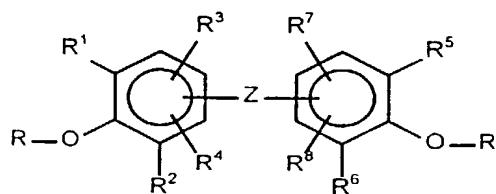
Further, R" may have an aryl structure. It is to note that each of the carbon atoms of R may carry 1, 2 or, if it is a terminal carbon atom, 3 fluorine atoms. Fully fluorinated carbon atoms (-CF₃, -CF₂-) are preferred. Further, it is preferred that one or both of R' are hydrogen and/or one of R" is fluorine or a partly or

fully fluorinated alkyl and the other is a partly or, more preferable, fully fluorinated alkyl which may be straight, branched or cyclic. Specific examples for the cyanates of formula IIIb are N≡C-O-CH₂-CF₂-CF₃, N≡C-O-CH₂-C(CF₃)₂F, N≡C-O-CH₂-CF₂-CF₂-CF₃, N≡C-O-CH₂-CHF-CF₂-CF₂-CF₃,

30 N≡C-O-CH₂-CF₂-CF₂-CF₂-CF₂-CF₃, N≡C-O-CH₂-CF₂-CF=CF-CF₂-CF₂-CF₃.

Specific examples for formula IIIa are phenylcyanate, 4-bromo-phenylcyanate, perfluorophenylcyanate, 3-trifluoromethyl-phenylcyanate.

Alternatively or in addition, the properties of the polymeric cyanates thus obtained may be modified by incorporating one or more phenols having either formula IIIa above or formula IIIc:



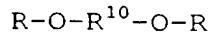
IIIc

wherein Z and R¹ to R⁸ are as defined above for the dicyanates of formula I, but wherein R is hydrogen. The phenols may, but must not necessarily, be partly or fully fluorinated. Examples are

10 2,2-bis(4-hydroxyphenyl)propane,
 2,2-bis(4-hydroxyphenyl)hexafluoropropane,
 biphenylene-4,4'-diphenol,
 2,3,5,6,2',3',5',6'-octafluorobiphenylene-4,4'diphenol.

15 Alternatively or in addition, the properties of the polymeric cyanates thus obtained may be modified by incorporating one or more monoalcohols having formula IIIb wherein R¹¹ is as defined above, and wherein R is hydrogen. Examples are HO-CH₂-CF₂-CF₃, HO-CH₂-C(CF₃)₂F, HO-CH₂-CF₂-CF₂-CF₃, HO-CH₂-CHF-CF₂-CF₂-CF₃,
 20 HO-CH₂-CF₂-CF₂-CF₂-CF₂-CF₃, HO-CH₂-CF₂-CF=CF-CF₂-CF₂-CF₃.

Alternatively or in addition, the properties of the polymeric cyanates thus obtained may be modified by incorporating one or more non-aromatic dihydroxy compounds having formula IIId



IIIId

wherein R is hydrogen and R¹⁰ is as defined for the dicyanates of formula II above. Examples are HO-CH₂-CF₂-CF₂-CH₂-OH,
 30 HO-CH₂-CF₂-CF₂-CF₂-CF₂-CH₂-OH, HO-CH₂-CF₂-CF₂-CF₂-CF₂-CF₂-CH₂-OH.

Alternatively or in addition, the properties of the polymeric cyanates thus obtained may be modified by incorporating one or more glycidethers of formulas IIIa to IIIc wherein R is glycidyl, and R¹ to R⁹, R¹¹ and Z are defined as above.

5 Specifically, the refractive index may be influenced by these additives as desired. Thus, as detailed more specifically below, the presence of fluorine lowers the refractive index, while it is increased by the presence of bromine. In addition, by
10 controlling the amount of glycidylic groups or the ratio of non-aromatic groups (especially of straight alkyl(ene) groups) to aromatic groups, this parameter may further be adjusted as required in order to obtain the desired refractive index difference between the cyanate polymer and the PFCB.

15 The polycyanate resins (polymeric cyanates) according to the invention may preferably be obtained by (co)polymerizing at least one of the difunctional cyanates of formula I, optionally together with at least one of the other substances as mentioned
20 above. Use of the said substances may be advantageous in order to further vary or improve the refractive index or other properties, e.g. compounding, moulding, or other optical properties.

25 If more than one difunctional cyanate is used in the preparation of the polycyanate, the ratio of the different difunctional cyanates may be freely chosen. Instead, the polymeric cyanates may be prepared using only one of the said difunctional cyanates of formula I. If additional components are present, the ratio is
30 usually not critical. Preferably, the difunctional cyanates of formula I and optionally formula II are present in a molar amount of at least 25%, more preferred of at least 50%, and specifically preferred not more than 67% related to the total amount of moles of monomers present in the mixture to be (co-
35)polymerized. If one or more monocyanates are added to the mixture, they are preferable present in an amount of up to 20 % or 25 % by mol per mol of monomers to be polymerized. If phenols or alcohols are present, they are preferably present in an

amount of up to about 60 or 65 mol-%. If glycidethers are added, they are preferably present in an amount of up to about 60 or even about 70 mol-%. Preferably, the monomer non-cyanates are incorporated in a total amount of not more than about 65 to 70 mol-% per mol of the total monomers to be polymerized.

The starting compounds for the polymeric cyanate as described above are preferably warmed up after mixing. The temperature may be chosen as required; a range of about 120°C to 170°C is preferred. Preferably, the reaction is performed in the absence of oxygen, e.g. in a sealed vessel (under an inert gas atmosphere). The mixture is allowed to react until a liquid or viscous prepolymer (resin) is obtained. This prepolymer or resin is soluble in useful solvents, preferably in solvents having high polarity, e.g. ethylethoxyacetate or chlorobenzene. In general, the prepolymer is processed in a respective solution, e.g. by spin-coating of a solution containing 25 to 75% by weight of the prepolymer, more preferably about 50% by weight of the prepolymer. The prepolymer solution may be applied to a suitable substrate or the like, consisting of e.g. silicon, quartz or an organic polymer, or onto a buffer layer, e.g. of PFCB. After being brought into the desired shape (e.g. into a layer of desired thickness) it is cured (e.g. at temperatures in the range of 200° to 260°C) in order to provide the desired network between the cyanate groups.

It should be clear that the term "resin" is independent of the condition of the polymeric cyanate, e.g. whether it is in a prepolymerized condition or is partly or completely cured.

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The polycyanate resins according to the present invention have a glass transition temperature in the range of 100° to 300°C, and their refractive index at 1.55μm may be controlled in the desired range, specifically of from about 1.40 to about 1.60. 35 Specifically, the more fluorinated monomers are used, or the more fluorine parts per weight are present in the mixture, related to the weight of the mixture to be polymerized, the lower is the refractive index of the polycyanate copolymer

obtained. This is especially the case if fully fluorinated alkyl(ene) chains are contained in the molecule. On the other hand, use of brominated derivatives of the cyanate monomers as defined above will raise the refractive index of the copolymer obtained. Thus, monomer compounds of e.g. formula IIIa wherein at least one of R¹, R², R³, R⁴ or R⁵ or of e.g. formula IIIb wherein R¹⁰ carries at least one bromine atom and R is N≡C, may be advantageously added to the mixture. Instead or in addition, brominated polyfunctional cyanates may also be used.

10

The polycyanate resins according to the present invention are used for the preparation of optical waveguide systems or waveguide structures, together with PFCB. PFCB as well as polycyanate resins may be applied in a dissolved state, e.g. by spin-coating. For such structures, PFCB may be used as a waveguide, while polycyanate resin is used as the material for buffer and/or cladding, the refractive index of the polycyanate resin being lower than that of the PFCB. Alternatively, PFCB may be used for buffer and/or cladding, while a polycyanate resin having a greater refractive index is used for the waveguide. In the preparation of such a waveguide structure, each layer applied is preferably cured (e.g. thermally) before the next, different layer is applied. For example, a first layer of either PFCB or polycyanate is spin-coated onto a suitable substrate, e.g. silicon, quartz, or an organic polymer, and is cured. If this layer shall serve as a buffer layer, the second layer serving as waveguide is made from the other material mentioned. Following curing, structurization may be performed e.g. via reactive ion etching (RIE) after this second layer has been sputtered with aluminum, and the etching mask is subsequently removed in a chemical etching bath. Last, a layer of the first material (or a material different to the first one, but having the same refractive index) is spin coated and cured, in order to provide the cladding layer. Alternatively, any one of the layers mentioned may be substituted by another material. Such materials are known in the art (e.g. SiO₂ as buffer).

The selection of suitably matching resins for waveguide, cladding, and optionally the buffer will be easily made by a skilled person who is able to control the refractive index via the teachings given in this application. The layers show 5 excellent adhesion to each other and to the substrate.

The invention is now further illustrated by way of examples.

Example 1

10 12.9 g of a substituted dicyanate of Bisphenol A (compound I wherein R¹-R⁴ is H, R⁵-R⁸ is H, Z is hexafluoroisopropyl) and 3.7 g of a partly fluorinated monocyanate (compound IIIb wherein R is CN and R¹¹ is CH₂-CF₂-CF₂-CF₃) are heated to 160°C in a sealed 15 vessel for a time of four hours. The reaction is terminated before gelling starts, and a clear, pale yellow prepolymer is obtained which is viscous at 160°C and is solid at room temperature. The prepolymer is brought into solution by mixing it with 50 % by weight of ethylethoxyacetate (EEA). Spin-coating 20 of this solution onto a substrate made of silicon wafer yields a layer which may be cured at 240°C for one hour in a drying oven. The product has a refractive index of 1.4776 at 1.55 µm.

Example 2

25 15.5 g of a partly fluorinated dicyanate (compound II wherein R¹⁰ is CH₂-CF₂-CF₂-CF₂-CF₂-CH₂) and 3.5 g dicyanate of bisphenol A (compound I wherein R¹-R⁴ is H, R⁵-R⁸ is H, Z is isopropyl) are heated to 160°C in a sealed vessel for a time of about six 30 hours. The reaction is terminated before gelling starts, and a clear, pale yellow prepolymer is obtained which is viscous at 160°C and is solid at room temperature. The prepolymer is brought into solution by mixing it with 50 % by weight of EEA. Spin-coating of this solution onto a substrate made of silicon 35 wafer yields a layer which is cured at 240°C for one hour in a drying oven. The product has a refractive index of 1.4739 at 1.55 µm.

Example 3

10.6 g of a substituted dicyanate of Bisphenol A (compound I wherein R¹-R⁴ is H, R⁵-R⁸ is H, Z is hexafluoroisopropyl) 3.1 g of 5 a partly fluorinated dicyanate (compound II wherein R¹⁰ is CH₂-CF₂-CF₂-CF₂-CF₂-CH₂) and 3.0 g of a monocyanate (compound IIIa wherein R is CN, R¹, R², R⁴, R⁵ is H, R³ is Br) are heated to 160°C in a sealed vessel for a time of four hours. The reaction is terminated before gelling starts, and a clear, pale yellow 10 prepolymer is obtained which is viscous at 160°C and is solid at room temperature. The prepolymer is brought into solution by mixing it with 50 % by weight of EEA. Spin-coating of this solution onto a substrate made of silicon wafer yields a layer which may be cured at 240°C for one hour in a drying oven. The 15 product has a refractive index of 1.4958 at 1.55 μm.

Example 4

6.9 g of a substituted dicyanate of Bisphenol F (compound I 20 wherein R¹, R², R⁵, R⁶ is CH₃, R³, R⁴, R⁷, R⁸ is H, Z is CH₂) 5.2 g of a partly fluorinated dicyanate (compound II wherein R¹⁰ is CH₂-CF₂-CF₂-CF₂-CF₂-CH₂) and 3.0 g of a partly fluorinated alcohol (compound IIIb wherein R is H, R¹¹ is CH₂-CF₂-CF₂-CF₃) are heated to 140°C in a sealed vessel for a time of five hours. The 25 reaction is terminated before gelling starts, and a clear, pale yellow prepolymer is obtained which is viscous at 140°C and is solid at room temperature. The prepolymer is brought into solution by mixing it with 50. % by weight of EEA. Spin-coating of this solution onto a substrate made of silicon wafer yields a layer which may be cured at 240°C for one hour in a drying oven. The 30 product has a refractive index of 1.4780 at 1.55 μm.

Example 5

12.9 g of a substituted dicyanate of Bisphenol A (compound I
5 wherein R¹-R⁴ is H, R⁵-R⁸ is H, Z is hexafluoroisopropyl), and 3.0
g of a fully fluorinated monocyanate (compound IIIb wherein R is
CN, R¹¹ is C-(CF₃)₂) are heated to 130°C in a sealed vessel for a
time of four hours. The reaction is terminated before gelling
starts, and a clear, pale yellow prepolymer is obtained which is
10 viscous at 130°C and is solid at room temperature. The
polymer is brought into solution by mixing it with 50 % by
weight of EEA. Spin-coating of this solution onto a substrate
made of silicon wafer yields a layer which may be cured at 240°C
for one hour in a drying oven. The product has a refractive
15 index of 1.4756 at 1.55 μm.

Example 6

A 50 weight-% solution of the prepolymer of example 1 in EEA is
20 spin-coated onto a silicon wafer, yielding a layer of about 8 μm
thickness. Curing is performed at 240°C in a drying oven for one
hour. Onto this cured layer, a PVCB solution (XU 35121.41 of The
Dow Chemical Company) is spin-coated, again yielding a layer of
25 8 μm thickness. Also, this layer is cured at 240°C in the drying
oven for about 1 hour. According to known methods, an aluminum
layer of about 100 nm is sputtered onto the said PFCB layer
followed by its structurization by way of photolithography and
chemical etching. Subsequently, the PFCB waveguides are
30 structured by aid of oxygen RIE technique (typical rate 100
nm/min using pure oxygen), and the etching mask is removed by
treatment in a chemical etching bath. Then, the upper cladding
layer is applied by spin-coating another prepolymer solution as
described in example 1 followed by curing at 240°C for 1 hour.
Using near field technique a difference of 0.0085 of the
35 refractive index between the waveguide and its surrounding is
measured. Cut-back measurements of light intensities of
waveguides of different length yielded a loss of 0.35 dB/cm at
1.55 μm.

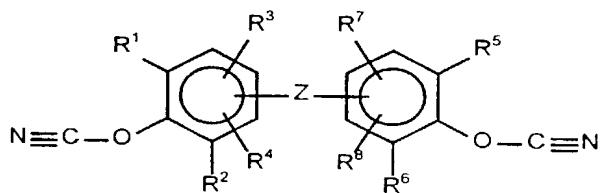
Example 7

A 50 weight-% solution of PFCB (XU 35121.41 of The Dow Chemical Company) is spin-coated onto a silicon wafer, yielding a layer of about 8 μm thickness. Curing is performed at 240°C in a drying oven for one hour. Onto this cured layer, the prepolymer of example 3 (50 weight-% in EEA solution) is spin-coated, again yielding a layer of 8 μm thickness. Also, this layer is cured at 240°C in the drying oven for about 1 hour. According to known methods, an aluminum layer of about 100 nm is sputtered onto the said PFCB layer followed by its structurization by way of photolithography and chemical etching. Subsequently, the PFCB waveguides are structured by aid of oxygen RIE technique (typical rate 100 nm/min using pure oxygen), and the etching mask is removed by treatment in a chemical etching bath. Then, the upper cladding layer is applied by spin-coating the same PFCB solution as described above followed by curing at 240°C for 1 hour. Using near field technique a difference of 0.0096 of the refractive index between the waveguide and its surrounding is measured. Cut-back measurements of light intensities of waveguides of different lenght yielded a loss of 0.43 dB/cm at 1.55 μm .

* * *

Claims:

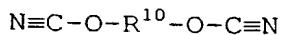
1. Optical waveguide system or waveguide structure comprising at least (a) a first material which is a poly(perfluorocyclobutane), and in direct contact to this material (b) a second material which is a polycyanate resin, wherein the said polycyanate resin has been (co)polymerized from at least one difunctional cyanate of formula I:



(I)

wherein R¹ to R⁸ are independently from each other hydrogen, optionally substituted C₁-C₁₀ alkyl, C₃-C₈ cycloalkyl, C₁-C₁₀ alkoxy, halogen, phenyl or phenoxy, the alkyl or aryl groups being unfluorinated, partly fluorinated or fully fluorinated, with the proviso that (I) carries at least 1 fluorine atom, and Z is a chemical bond, SO₂, CF₂CH₂, CHF, CH(CH₃), isopropylene, hexafluoroisopropylene, n- or iso-C₁-C₁₀ alkylene which may be partly or fully fluorinated, O, NR⁹ whereby R⁹ is hydrogen or C₁-C₁₀ alkyl, N=N, CH=CH, C(O)O, CH=N, CH=N-N=CH, alkyloxyalkylene having 1 to 8 carbon atoms, S, or Si(CH₃)₂.

2. Optical waveguide system or waveguide structure as claimed in claim 1, wherein the said polycyanate resin has been copolymerized from at least one dicyanate of formula I and at least one difunctional cyanate of formula II:



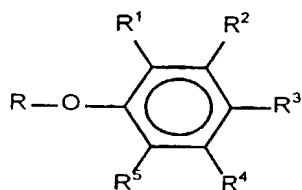
(II)

wherein R¹⁰ is C(R')₂-R''-C(R')₂, wherein each R' is,

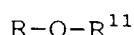
independently from the other, hydrogen or fluorine or an optionally substituted, preferably fluorinated alkyl or alkenyl group, and R" is a non-aromatic hydrocarbon group or may have an arylenic structure,

5 with the proviso that (II) carries at least one fluorine atom.

3. Optical waveguide system or waveguide structure as claimed in claim 1 or 2, wherein the said polycyanate resin has been copolymerized from at least one dicyanate of formula I, 10 optionally at least one difunctional cyanate of formula II, and at least one of the following compounds: monocyanates having formula IIIa or IIIb:



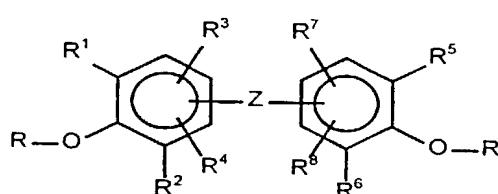
IIIa



IIIb

wherein R¹ to R⁵ are as previously defined for the dicyanate of formula I, R is N≡C- and R¹¹ is a straight, branched, or cyclic non-aromatic hydrocarbon radical or a non-aromatic hydrocarbon radical comprising a cyclic structure,

25 phenols having either formula IIIa above or formula IIIc:



IIIc

wherein Z and R¹ to R⁸ are as defined above for formula I and

R is hydrogen,

monoalcohols having formula IIIb wherein R¹¹ is as defined above, and wherein R is hydrogen,

5

non-aromatic dihydroxy compounds having formula Vd

R-O-R¹⁰-O-R

Vf

10

wherein R is hydrogen and R¹⁰ is as defined for the dicyanates of formula IV above,

and

15

glycidethers of formulas IIIa to IIIc wherein R is glycidyl, the other radicals being as defined above.

4. Optical waveguide system or waveguide structure as claimed in any of claims 1 to 3, wherein both the first and the second 20 materials are in the form of a thin layer, the layers directly adhered to each other.
5. Optical waveguide system or waveguide structure according to claim 4, wherein either the waveguide is made of the first material and at least one of the buffer layer and the 25 cladding layer is made of the second material, or the waveguide is made of the second material and at least one of the buffer layer and the cladding layer is made of the first material.

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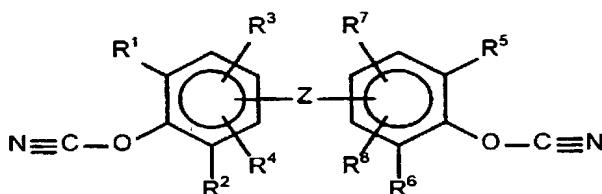
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(54) Title: **OPTICAL WAVEGUIDES DERIVED FROM A COMBINATION OF POLY(PERFLUOROCYCLOBUTANES) AND POLYMERIC CYANATES**



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being unfluorinated, partly fluorinated or fully fluorinated, with the proviso that (I) carries at least 1 fluorine atom, and Z is a chemical bond, SO₂, CF₂CH₂, CHF, CH(CH₃), isopropylene, hexafluoroisopropylene, n- or iso-C₁-C₁₀ alkylene which may be partly or fully fluorinated, O, NR⁹ whereby R⁹ is hydrogen or C₁-C₁₀ alkyl, N=N, CH=CH, C(O)O, CH=N, CH=N-N=CH, alkoxyalkylene having 1 to 8 carbon atoms, S, or Si(CH₃)₂, optionally in mixture with other components. Preferably, both the first and the second materials are in the form of a thin layer, the layers directly adhered to each other. Either the waveguide can be made from the first material and at least one of the buffer layer and the cladding layer can be made from the second material, or vice versa.

(57) Abstract: The present invention is directed to optical waveguides or waveguide systems, comprising at least (a) a first material which is a poly(perfluorocyclobutane), and in direct contact to this material, (b) a second material which is a polycyanate resin made from at least one aromatic difunctional cyanate of formula (I) wherein R¹ to R⁸ are independently from each other hydrogen, optionally substituted C₁-C₁₀ alkyl, C₃-C₈ cycloalkyl, C₁-C₁₀ alkoxy, halogen, phenyl or phenoxy, the alkyl or aryl groups

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**OPTICAL WAVEGUIDES DERIVED FROM A COMBINATION OF
POLY(PERFLUOROCYCLOBUTANES) AND POLYMERIC CYANATES**

the specification of which:

is attached hereto; or

was filed as United States Application Serial No. 10/019,479
on December 31, 2001, and was amended on December 31, 2001
(if applicable); or

was filed as PCT International Application Number PCT/EP00/06205
on July 3, 2000 and was amended on _____
(if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

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Country	Application Number	Date of Filing	Priority Claimed Under 35 U.S.C. 119
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Application Number	Date of Filing

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I hereby appoint the following attorney and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. **FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P.**, Reg. No. 22,540, Douglas B. Henderson, Reg. No. 20,291; Ford F. Farabow, Jr., Reg. No. 20,630; Arthur S. Garrett, Reg. No. 20,338; Donald R. Dunner, Reg. No. 19,073; Brian G. Brunsbold, Reg. No. 22,593; Tipton D. Jennings IV, Reg. No. 20,645; Jerry D. Voight, Reg. No. 23,020; Laurence R. Hefter, Reg. No. 20,827; Kenneth E. Payne, Reg. No. 23,098; Herbert H. Mintz, Reg. No. 26,691; C. Larry O'Rourke, Reg. No. 26,014; Albert J. Santorelli, Reg. No. 22,610; Michael C. Elmer, Reg. No. 25,857; Richard H. Smith, Reg. No. 20,609; Stephen L. Peterson, Reg. No. 26,325; John M. Romary, Reg. No. 26,331; Bruce C. Zotter, Reg. No. 27,680; Dennis P. O'Reilley, Reg. No. 27,932; Allen M. Sokal, Reg. No. 26,695; Robert D. Bajefsky, Reg. No. 25,387; Richard L. Stroup, Reg. No. 28,478; David W. Hill, Reg. No. 28,220; Thomas L. Irving, Reg. No. 28,619; Charles E. Lipsey, Reg. No. 28,165; Thomas W. Winland, Reg. No. 27,605; Basil J. Lewis, Reg. No. 28,818; Martin I. Fuchs, Reg. No. 28,508; E. Robert Yoches, Reg. No. 30,120; Barry W. Graham, Reg. No. 29,924; Susan Haberman Griffen, Reg. No. 30,907; Richard B. Racine, Reg. No. 30,415; Thomas H. Jenkins, Reg. No. 30,857; Robert E. Converse, Jr., Reg. No. 27,432; Clair X. Mullen, Jr., Reg. No. 20,348; Christopher P. Foley, Reg. No. 31,354; John C. Paul, Reg. No. 30,413; David M. Kelly, Reg. No. 30,953; Kenneth J. Meyers, Reg. No. 25,146; Carol P. Einaudi, Reg. No. 32,220; Walter Y. Boyd, Jr., Reg. No. 31,738; Steven M. Anzalone, Reg. No. 32,095; Jean B. Fordis, Reg. No. 32,984; Barbara C. McCurdy, Reg. No. 32,120; James K. Hammond, Reg. No. 31,964; Richard V. Burgujian, Reg. No. 31,744; J. Michael Jakes, Reg. No. 32,824; Dirk D. Thomas, Reg. No. 32,600; Thomas W. Banks, Reg. No. 32,719; Christopher P. Isaac, Reg. No. 32,616; Bryan C. Diner, Reg. No. 32,409; M. Paul Barker, Reg. No. 32,013; Andrew Chanho Sonu, Reg. No. 33,457; David S. Forman, Reg. No. 33,694; Vincent P. Kovalick, Reg. No. 32,867; James W. Edmondson, Reg. No. 33,871; Michael R. McGurk, Reg. No. 32,045; Joann M. Neth, Reg. No. 36,363; Gerson S. Panitch, Reg. No. 33,751; Cheri M. Taylor, Reg. No. 33,216; Charles E. Van Horn, Reg. No. 40,266; and Linda A. Wadler, Reg. No. 33,218; Jeffrey A. Berkowitz, Reg. No. 36,743; Michael R. Kelly, Reg. No. 33,921; James B. Monroe, Reg. No. 33,971; Doris Johnson Hines, Reg. No. 34,629; Allen R. Jensen, Reg. No. 28,224; Lori Ann Johnson, Reg. No. 34,498; and David A. Manspeizer, Reg. No. 37,540 and _____ Please address all correspondence to **FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P.**, 1300 I Street, N.W., Washington, D.C. 20005, Telephone No. (202) 408-4000.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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